Measuring systemic risk

Measuring Systemic Risk: A Comparison of Alternative Market-Based Approaches

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Abstract

This paper compares four commonly used systemic risk metrics using data on U.S. financial institutions over the period 2005-2014. The four systemic risk measures examined are the (i) marginal expected shortfall, (ii) codependence risk, (iii) delta conditional value at risk, and (iv) lower tail dependence. Our results demonstrate that the alternative measurement approaches produce very different estimates of systemic risk. Furthermore, we show that the different systemic risk metrics may lead to contradicting assessments about the riskiness of different types of financial institutions. Overall, our findings suggest that systemic risk assessments based on a single risk metric should be approached cautiously.

JEL classification: G01; G21; G32; G33; G34

Keywords: systemic risk; marginal expected shortfall; codependence risk; delta conditional value at risk; lower tail dependence; bank risk-taking; financial crisis

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1. Introduction

This paper focuses on the measurement of systemic risk. Specifically, we empirically compare four commonly used market-based systemic risk measures using data on U.S. financial institutions over the period 2005-2014. The four systemic risk measures examined in this study are the marginal expected shortfall (MES) proposed by Acharya et al. (2012), the codependence risk (Co-Risk) of Chan-Lau et al. (2009), the delta conditional value at risk (ΔCoVaR) proposed by Adrian and Brunnermeier (2009), and the lower tail dependence (LTD) developed by Weiß et al. (2014). We aim to analyze differences in the systemic risk estimates produced by the alternative measurement approaches and we also evaluate the performance of the four alternative risk metrics over time and across different types of financial institutions.

In the aftermath of the global financial crisis, considerable attention has been devoted to the measurement of systemic risk and a plethora of alternative risk metrics have been proposed in the literature (for surveys, see Biasis et al., 2012 and Hattori et al., 2014). The alternative approaches for measuring systemic risk can be broadly classified into measures based on balance sheet variables (accounting-based), interbank data (exposures and cash flows) and on financial market data (market-based). Regardless of the approach, the different metrics intend to quantify the level of systemic risk of financial institutions. In this paper, we contribute to the growing body of literature by providing a systematic comparison of four commonly used market-based systemic risk measures.

Despite the recent efforts devoted to the measurement of systemic risk, surprisingly little is known about the relative performance of the alternative measurement approaches proposed in the literature. A general dilemma, of course, is that the “true” level of systemic risk is unobservable, and therefore, it is somewhat debatable whether the proposed systemic risk metrics even measure

the underlying phenomenon. Typically, the studies that present new approaches for measuring systemic risk argue that the proposed measures provide good estimates of systemic risk by relating the pre-crisis systemic risk levels to the government capital injections or bank failures during the crisis. Some prior studies have documented that the market-based risk metrics proposed in the literature may produce counterintuitive estimates of systemic risk (e.g., Guntay and Kupiec, 2014; Löffler and Raupach, 2015), while other studies have shown that systemic risk measures are closely linked with the traditional risk measures such as systematic risk and value-at-risk (e.g., Benoit et al., 2013; Adrian and Brunnermeier, 2014; Kleinow and Nell, 2015).

Our empirical analysis is most closely related to recent studies by Rodríguez-Moreno and Peña (2013), Benoit et al. (2013), and Hattori et al. (2014). Rodríguez-Moreno and Peña (2013) compare market-based systemic risk estimates which are derived from the interbank rates, stock prices, or credit default swap spreads. Their findings indicate that the metrics based on credit default swap spreads provide better estimates of systemic risk than the metrics derived from interbank rates or stock prices. Benoit et al. (2013) provide a theoretical and empirical comparison of market-based systemic risk measures using data on U.S. financial institutions. Their analysis demonstrates that the commonly used systemic risk metrics are transformations of the traditionally used market risk measures. Furthermore, Benoit et al. (2013) document that different metrics may lead to conflicting identification of systemically important financial institutions. Finally, Hattori et al. (2014) compare systemic risk metrics by assessing changes in systemic risk estimates around several financial crises in Japan. They document systematic increases in the level of systemic risk during crisis periods, suggesting that the measures of systemic risk are able to accurately describe Japanese financial crises.

Our study also complements a small body of literature on the interconnectedness of different segments of the financial industry. Billio et al. (2012) examine the interconnectedness of banks, insurance companies, brokers/dealers, and hedge funds. Their results indicate that different types of financial institutions have become very interrelated, with banks making the largest contribution to the level of systemic risk. Chen et al. (2014) focus on the systemic risk linkages between banks and insurance companies. Consistent with findings of Billio et al. (2012), they document that banks are more important than insurance companies in terms of systemic risk.

In our empirical analysis, four alternative market-based systemic risk metrics (MES, Co-Risk, ΔCoVaR, and LTD) are estimated and compared using daily stock return data for 122 individual U.S. financial institutions over the period 2005-2014. We categorize the individual financial institutions into banks, non-depository financial institutions, and insurance companies, and then compare the systemic risk metrics across these three distinct segments of the financial industry. Furthermore, given that institution size is an important determinant of systemic risk (e.g., Pais and Stork, 2013; Iqbal et al., 2015), we also perform comparisons of the alternative risk metrics separately for large and small financial institutions.

Our empirical findings demonstrate that different measurement approaches produce very different estimates of systemic risk. Interestingly, we document that the alternative market-based systemic risk metrics may lead to contradicting assessments about the riskiness of different types of financial institutions. The outcomes of the alternative systemic risk measures seem to vary considerably within and between the three segments of the financial industry, and moreover, also between large and small institutions. The results further indicate that the alternative systemic risk metrics behave very inconsistently with each other over time. For instance, the systemic risk

estimates produced by MES and ΔCoVaR seem to move into opposite directions amidst the severe financial market turmoil in 2008. Overall, our findings suggest that systemic risk assessments which are based on a single risk metric should be approached cautiously.

The remainder of the paper proceeds as follows. Section 2 presents the four alternative market-based systemic risk measures and Section 3 describes the data. The results of our empirical analysis are reported in Section 4. Finally, Section 5 provides concluding remarks.

2. Systemic risk measures

We compare the following four market-based systemic risk measures: (i) the marginal expected shortfall (MES), (i) codependence risk (Co-Risk), (iii) delta conditional value at risk (ΔCoVaR), and (iv) the lower tail dependence (LTD).

The MES developed by Acharya et al. (2012) is defined as the expected daily percentage decrease in equity value of a financial institution when the aggregate national stock market declines by at least 2 percent on a single day. The Co-Risk proposed by Chan-Lau et al. (2009) aims to quantify how the riskiness of one financial institution affects the riskiness of other institutions amidst periods of market turmoil. The Co-Risk approach utilizes quantile regressions to estimate the level of systemic linkages across financial institutions in adverse market conditions. The ΔCoVaR developed by Adrian and Brunnermeier (2009) defines the systemic risk contribution of a financial institution as the difference between its value-at-risk measures conditional on being in distress and not being in distress. Finally, the LTD introduced by Weiß et al. (2014) aims to measure the probability of a simultaneous extreme, lower tail event in the financial sector as a whole and the equity values of individual financial institutions. The LTD is

estimated from the joint probability return distributions of individual financial institutions and the industry index.

Although some of the market-based systemic risk measures can be estimated using data on credit default swap spreads or other fixed income instruments, we use daily stock return data supplemented with other measure-specific data to estimate the systemic risk of financial institutions. The use of the same stock return data facilitates comparisons of the four alternative measurement approaches and minimizes data-driven differences in the systemic risk estimates produced by the different metrics. Furthermore, although we estimate the level of systemic risk for individual financial institutions, we compare the alternative measures based on aggregated systemic risk levels across three industry segments (banks, non-depository financial institutions, and insurance companies), and two size categories (below and above the median market capitalization).

3. Data

Our empirical analysis is based on a sample of U.S. financial institutions. Specifically, we collect daily stock return data from CRSP over the period 2005-2014 for all companies which have an SIC code between 6000 and 6799. The sample comprises a total number of 122 individual financial institutions which we categorize based on the SIC codes into 49 banks, 43 non-depository financial institutions, and 30 insurance companies. Our sample period provides an expedient setting for examining systemic risk measures as it encompasses several years before the global financial crisis, the period of severe market turmoil of 2008-2009, as well as several years in the aftermath of the crisis. In addition to stock return data, we use financial data from Compustat, interest rate, yield curve, and corporate credit spread data from the Federal Reserve,

and general collateral repo data obtained from DTCC Solutions LCC in the systemic risk calculations.

4. Results

Table 1 presents the descriptive statistics for the systemic risk estimates across three industry segments and two size categories. Overall, the descriptive statistics indicate that the four alternative systemic risk measures may lead to contradicting assessments about the level of systemic risk of different types of financial institutions. The mean and the median values of MES and Co-Risk suggest that large banks are the most systemically risky financial institutions, while the corresponding ΔCoVaR and LTD figures imply that large insurance companies make the largest contribution to systemic risk. Given the importance of institution size, it is not surprising that the descriptive statistics for MES, Co-Risk and LTD suggest that large financial institutions are associated with higher levels of systemic risk than small institutions. Based on ΔCoVaR, however, there seems to be no difference between large and small institutions in terms of systemic risk. It can be also noted from Table 1 that the between-firm variation of Co-Risk is considerably larger than the variation of the other three metrics. Co-Risk also displays the highest skewness and produces the largest systemic risk differences between large and small institutions.

(insert Table 1 about here)

Figures 1A-F depict the time-series of the four alternative systemic risk estimates for different types of financial institutions. To facilitate the comparison of the risk metrics, we

standardize each measure to take values between 0 and 1 with higher values indicating higher levels of systemic risk. Several interesting features emerge from the figures. Most importantly, the figures demonstrate that the four market-based metrics produce very different estimates of systemic risk, and may lead to somewhat contradicting assessments about the systemic riskiness of different types of financial institutions. Moreover, it can be noted from the figures that the alternative risk metrics behave inconsistently with each other over time.

(insert Figures 1A-F about here)

Figures 1A and 1B plot the systemic risk estimates for small and large banks. The time-series patterns of the MES, ΔCoVaR, and LTD estimates are very similar between small and large banks, although these three metrics seem to provide inconsistent estimates with each other over the years preceding the global financial crisis. Specifically, MES and LTD estimates increase considerably during the period 2005-2007, while ΔCoVaR estimates at the same time display a notable downward trend. Furthermore, the figures show that MES peaks amidst the financial crisis, whereas the highest values of Co-Risk, ΔCoVaR, and LTD are observed in years 2013, 2005, and 2011, respectively. In contrast to the other measures, the Co-Risk estimates between small and large banks differ significantly from each other and sometimes move into opposite directions. The Co-Risk estimates suggest that the level of systemic risk of small banks is very high from 2005 until a swift decrease in 2014, while large banks exhibit low levels of systemic risk until a sudden spike in 2013.

The systemic risk estimates for non-depository financial institutions and insurance companies are depicted in Figures 1C-1F. As can be seen from the figures, the four alternative measurement

approaches behave inconsistently with each other over time and produce very different estimates of systemic risk. Regardless of the type of institutions, MES increases considerably amidst the financial crisis in 2008. The Co-Risk and ΔCoVaR estimates for non-depository financial institutions plunge in 2011 at the same time with a considerable increase in the LTD estimates. For insurance companies, the ΔCoVaR estimates are at very high levels from 2005 until 2008, and then decrease drastically in 2009 only to reach high levels again in 2011. Similar to the Co-Risk estimates for banks, the Co-Risk estimates for non-depository financial institutions and insurance companies seem to be strongly affected by the size of the institutions.

5. Conclusions

This paper presents an empirical comparison of four commonly used systemic risk measures. The systemic risk metrics examined are the (i) marginal expected shortfall, (ii) codependence risk, (iii) delta conditional value at risk, and (iv) lower tail dependence. Using data on U.S. financial institutions, we evaluate the systemic risk estimates produced by the alternative measurement approaches over time and across different types of financial institutions.

Our empirical findings demonstrate that the four market-based measurement approaches produce very different estimates of systemic risk. The estimates produced by the different risk metrics vary considerably within and between the three segments of the financial industry as well as between larger and smaller institutions. Although it is difficult to draw common conclusions, non-depository institutions seem to be the least systemically risky segment according to the four measures. Furthermore, we find that the four alternative systemic risk measures behave inconsistently with each other over time, and may lead to contradictory assessments about the riskiness of different types of financial institutions. Out of the four measurement approaches, the

marginal expected shortfall appears intuitively most appealing as it accurately outlines the timeline of the global financial crisis by producing consistently high estimates of systemic risk for the three industry segments and the two size categories amidst the financial turmoil in 2008-2009. Overall, our findings suggest that the information provided by different systemic risk measures is quite heterogeneous, and therefore systemic risk assessments based on a single risk metric should be approached with caution.

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Table 1. Descriptive statistics.

Panel A: Banks

	N	Mean	Median	St. dev.	Min	Max
Small institutions:						
MES	25	-0.02	-0.02	0.02	-0.09	0.03
Co-Risk	25	78	317	4163	-47681	10000
ΔCoVaR	25	-0.56	-0.54	0.17	-1.45	0.15
LTD	25	0.24	0.24	0.16	0	0.63
Large institutions:						
MES	25	-0.04	-0.03	0.03	-0.14	-0.01
Co-Risk	25	607	282	1442	-3234	15451
ΔCoVaR	24	-0.56	-0.54	0.18	-1.63	0.34
LTD	25	0.42	0.4	0.14	0	0.8

Panel B: Non-depository financial institutions

	N	Mean	Median	St. dev.	Min	Max
Small institutions:						
MES	34	-0.01	-0.01	0.02	-0.11	0.02
Co-Risk	34	143	86	4740	-46524	38279
ΔCoVaR	22	-0.18	-0.05	0.39	-2.86	0.42
LTD	34	0.18	0.16	0.16	0	0.79
Large institutions:						
MES	33	-0.03	-0.02	0.03	-0.13	0
Co-Risk	33	-67	192	7736	-134694	32819
ΔCoVaR	21	-0.18	-0.06	0.4	-3.04	0.43
LTD	33	0.41	0.4	0.2	0	0.87

Panel C: Insurance companies

	N	Mean	Median	St. dev.	Min	Max
Small institutions:						
MES	19	-0.02	-0.02	0.02	-0.09	0.04
Co-Risk	19	224	178	40179	-351236	421682
ΔCoVaR	15	-1.81	-0.07	3.71	-10.03	0.4
LTD	19	0.24	0.24	0.17	0	0.64
Large institutions:						
MES	19	-0.03	-0.02	0.03	-0.17	0
Co-Risk	19	18	86	1022	-7676	1800
ΔCoVaR	15	-1.74	-0.07	3.65	-10.04	0.41
LTD	19	0.43	0.47	0.17	0	0.79

The table reports the descriptive statistics for the systemic risk estimates across three industry segments (banks, non-depository financial institutions, and insurance companies) and two size categories (below and above the median market capitalization). MES, Co-Risk, ΔCoVaR, and LTD denote the marginal expected shortfall, codependence risk, delta conditional value at risk, and lower tail dependence, respectively.

Figure 1A. Systemic risk of small banks.

Figure 1B. Systemic risk of large banks.

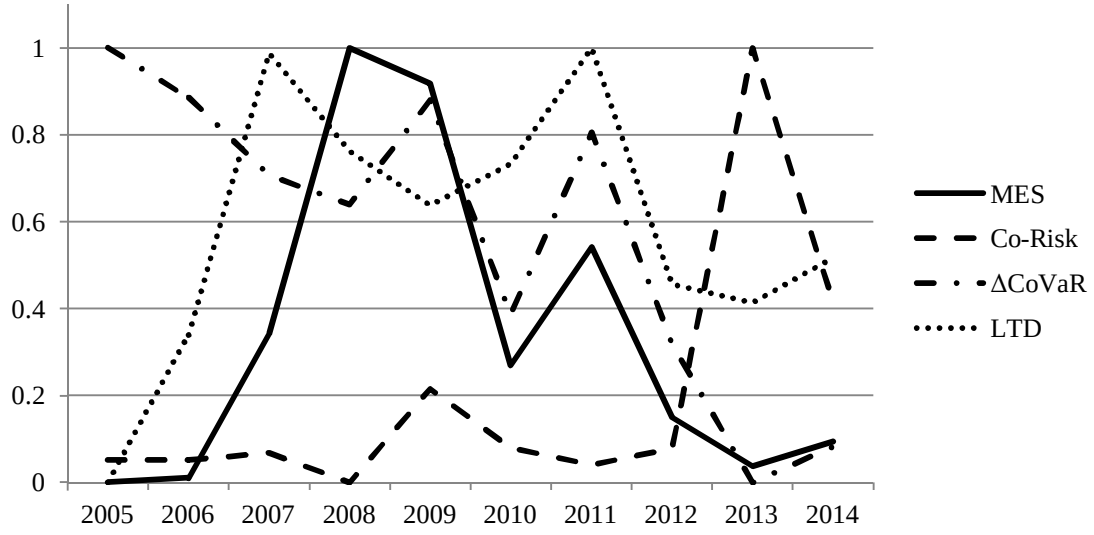


Figure 1C. Systemic risk of small non-depository financial institutions.

Figure 1D. Systemic risk of large non-depository financial institutions.

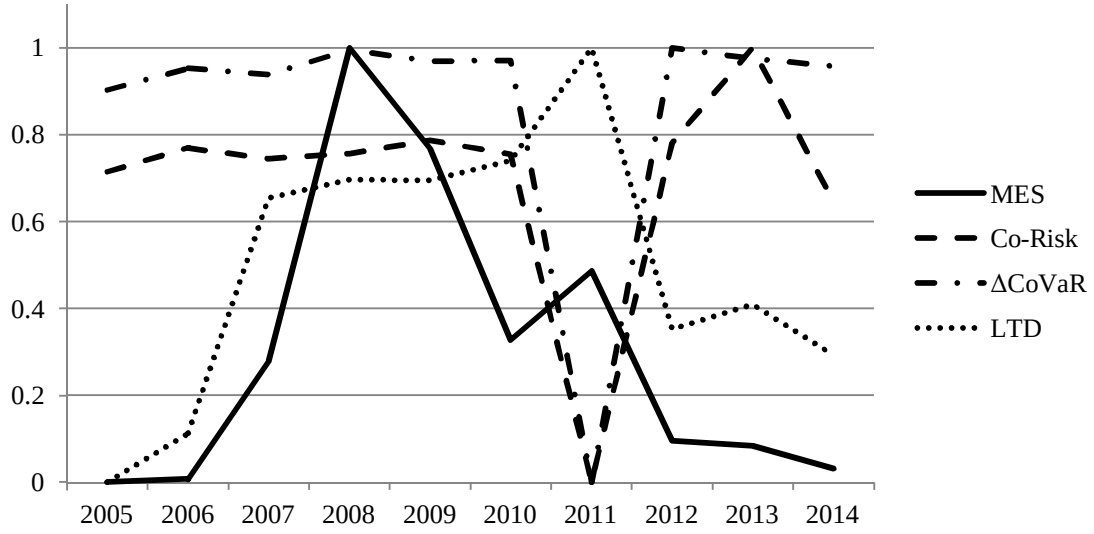
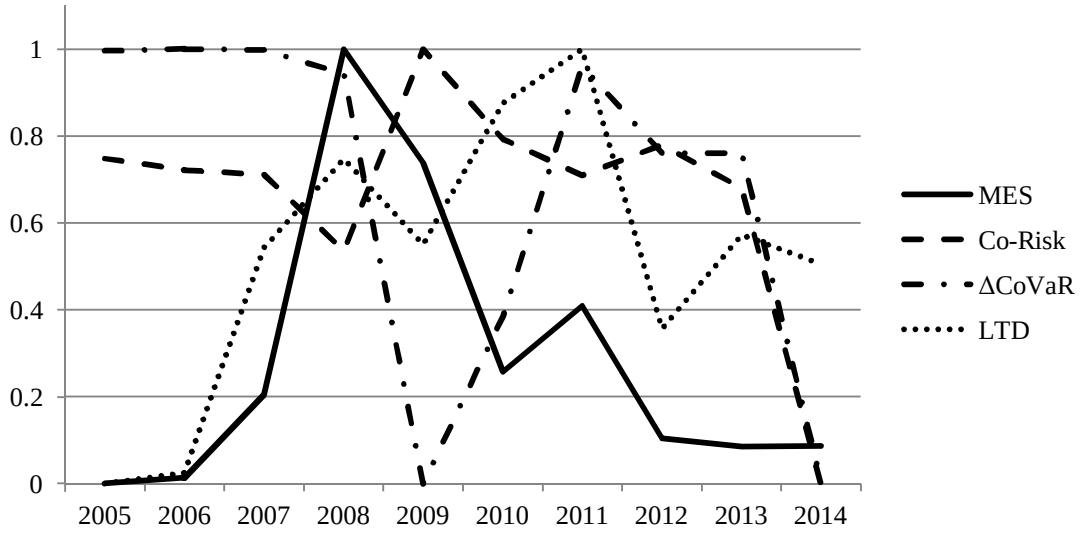


Figure 1E. Systemic risk of small insurers.

Figure 1F. Systemic risk of large insurers.



The figures plot the time-series of the systemic risk estimates across three industry segments (banks, non-depository financial institutions, and insurance companies) and two size categories (below and above the median market capitalization). MES, Co-Risk, ΔCoVaR, and LTD denote the marginal expected shortfall, codependence risk, delta conditional value at risk, and lower tail dependence, respectively. The systemic risk estimates are standardized to take values between 0 and 1 with higher values indicating higher levels of systemic risk.